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Canada

SELECTING INDICATORS FOR STATE OF THE ENVIRONMENT REPORTING

(DRAFT)

Report No. 8

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Table of Contents

		Page
1.0 INTRODUCTION		1
1.1	Background	1
1.2	Indicator Definition	2
1.3	Assessing the State of the Environment - A Complex Business	3
1.4	Role of SOE Reporting and Indicators	3
2.0 DESIRABLE CHARACTERISTICS OF SOE INDICATORS		6
2.1	Feasible to Obtain	6
2.2	Scientifically Credible	7
2.3	Understandable	8
2.4	Provide Early Warning Detection	9
2.5	Enable the Detection of Temporal and Spatial Trends	10
2.6	SOE Indicator Documentation	11
3.0 CURRENT AND PROPOSED INDICATOR RESEARCH INITIATIVES		11
3.1	Purpose of SOE Indicator Research	11
3.2	Where Do We Go From Here	12
3.3	Current SOE Branch Indicator Projects	13
3.4	Proposed SOE Branch Indicator Projects for 1989-1990	14
APPENDICES		
A	Organizational Framework for SOE Indicators	16
B	Quick-Reference Summary of SOE Indicator Criteria	20
REFERENCES		24

DRAFT
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SELECTING INDICATORS FOR

STATE OF THE ENVIRONMENT REPORTING

1.0 INTRODUCTION

1.1 Background

The federal government has recently established a national state of the environment (SOE) reporting program aimed at providing a better understanding of environmental conditions and trends to Canadians. Increased knowledge of these conditions and trends, and an understanding of why they are occurring is required for proactive environmental planning and management and informed decision-making.

An important step in establishing an SOE reporting process is to identify which indicators will be used to represent the state of the Canadian environment. The purpose of SOE indicators is to synthesize, out of a mass of inventory data, information on the state of the Canadian environment in a manner which is readily understandable by informed non-scientists including the public. To synthesize data in this way requires the development of indicators or indices which convey how the environment is responding to stress and management. Indicators should help determine how close the environment is to a desired state, whether it is moving towards or away from that state, and at what rate (Balser and Taylor, 1988, 3). While members of the SOE Branch can initiate and coordinate SOE indicator research, it is clear that data holders (including scientists, data experts, baseline program managers, subject matter specialists, etc.) play a critical role in identifying the most appropriate indicators for national SOE reporting. Indicator research, like the SOE reporting process, relies greatly on the input and cooperation of these experts across the country.

The remainder of section 1 of this document defines indicators and describes the role and purpose of SOE reporting and indicators. The indicator selection criteria presented in section 2 are generic and are not tied to a specific SOE product. They are meant to remind data holders of key criteria which should be considered when selecting indicators for SOE reporting in general. These criteria would probably become more specific for particular SOE products or applications. For example, acceptable time-frames for indicator availability would be different for the 5 year national assessment reports compared to annual water quality assessments. Finally, section 3 reviews current and proposed SOE Branch indicator research initiatives and proposes an approach to establish a national SOE indicator research program.

1.2 Indicator Definition

Single Measure Indicator

A review of the literature reveals that the term "indicator" has achieved widespread use in many disciplines including SOE reporting. Perhaps due to this widespread use, its meaning appears to have been expanded to the point where it is commonly used as a synonym for data. An indicator, in the context of this paper, is a variable used to "identify the presence or condition of a phenomenon that cannot be measured directly" (Thomas, 1972, 1). It is an alternative, surrogate, or proxy measure which is used when it is not technically or financially feasible to observe and/or record the actual phenomenon. An indicator may also serve to synthesize or summarize a series of other data variables. For example, the Inland Waters Directorate of Environment Canada collect dozens of water chemistry parameters, however, only a limited subset of the key parameters is required to provide a general picture of overall water quality.

All indicators must be correlated to the phenomenon under measurement. For example, in an analysis of surface water acidification for Nova Scotia (Howell et al, 1989, #), water colour was used as an indicator of organic acidification. This was possible because water colour is highly correlated to dissolved organic carbon (DOC) which is used for the calculation of organic anion concentration. Thus, high water colour represented surface waters which are acidified from naturally produced organic acids.

Composite Indicator or Index

It is possible to combine two or more indicators to derive a composite single value referred to as an index. Aggregation is normally achieved by assigning weights and/or ratings to individual indicators and their values and summing these into a total score. For example, the U.S. Pollutant Standard Index is based on the following five separate air pollutants: suspended particulate matter, ozone, nitrogen dioxide, carbon monoxide, and sulphur dioxide. A composite index is obtained by assigning a weight of importance to each variable and rating each air pollutant according to human health risks. These weights and ratings are in turn summed to obtain an overall score. Levels of human health risk are associated to these scores to help interpret their significance. For example, above a certain score it is recommended that the elderly or individuals with respiratory problems not go outdoors for extensive periods of time. Indices are commonly used in other disciplines such as business where, for example an index is used to provide the general daily change in the price levels of groups of stocks.

While indices give the appearance of integrated composite measures, caution is necessary in their use and interpretation. The weighting schemes used to derive indices tend to be subjective and inherent information loss may limit the insight they offer of the phenomenon

under study. However, if the index is designed properly, the lost information will not seriously distort the results provided by the data (Ott, 1978, 2).

1.3 Assessing the State of the Environment - A Complex Business

No Single SOE Indicator

An SOE indicator is a variable which provides a surrogate representation of environmental quality and/or assets (quantity). A common approach to studying a complex system such as the environment involves segmenting it into more specific and manageable components such as air, land, water, flora, and fauna. The composite state of each of these components, in turn, theoretically represents the overall state of the environment. Given the environment is a complex mosaic of interrelated components, "there is no single measure or index which can show in a meaningful and valid way what the state of the environment is and whether or not it is improving" (Elkin, 1987, 7). Instead, a series of carefully selected indicators is required to provide a profile of the overall state of the environment. An organizational framework identifying categories of information which are required for a **comprehensive environmental profile** is presented in section 1.4.

Need for SOE Indicator Selection Guidelines

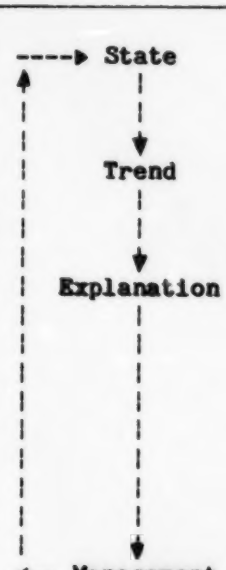
There are currently thousands of environmental data parameters which are captured as part of baseline inventory and survey programs in environmental, natural resource, and socioeconomic agencies. However, "... there is no general agreement with respect to the key parameters to measure environmental change" (Elkin, 1987, 7). As such, the development of an approach to select key SOE indicators, which together provide an accurate profile of the state of the Canadian environment, is a major challenge for the SOE Reporting Program. An important first step towards this goal is the identification of guidelines for selecting SOE reporting indicators (such guidelines are presented in section 2.0).

1.4 Role of SOE Reporting and Indicators

Value-Added of SOE Reporting

The SOE Reporting process inherently goes beyond simply identifying the state of the Canadian environment. It should provide an integrated and comprehensive assessment of how and why environmental conditions are changing, and communicate what the implications of these changes are to Canadians (see Figure 1). For example, the Science Council of Canada (1988, 17) explains that "the complex interconnectedness between conditions in the environment and their causes has led to the awareness of the importance of a holistic approach to the environment, one that incorporates the human race as an integrated part of the picture". While state of the environment reporting can serve to highlight problem areas which require attention, an understanding of how a particular state was obtained

is necessary to evaluate the appropriateness of existing policies, programs, and management practices and to implement appropriate remedial action to effectively manage environmental resources. By knowing which important environmental changes are occurring and understanding why they are occurring, Canadians and decision-makers alike will be able to respond in a more enlightened manner.



State	Inventory of environmental quality and assets (quantity) for one point in time.
Trend	A measure of environmental change over time and space designed to gauge deterioration, improvements, or stability.
Explanation	Why has the trend identified above occurred? An explanation requires an understanding of complex interrelationships between human activities, natural processes, and environmental conditions. This understanding is necessary for proactive environmental planning and management (below). Also, this understanding can be used to predict the implications of environmental changes to Canadians.
Management Response	Based on knowledge of environmental change trends and an understanding of why these have occurred, what actions or measures can Canadians take to improve or rectify the situation? Are existing policies or responses adequate? The actions taken by Canadians will in turn influence the state of the Canadian environment.

Figure 1: Model of the Value-added of the SOE Reporting Process

Organizational Framework for SOE Indicators

The need to understand why environmental changes are occurring has led to the adoption of organizational frameworks such as the stress-response model which distinguishes between indicators reflecting agents of environmental change (stress) and indicators of environmental conditions (response). A simplified version of the stress-response model is presented in Figure 2. In this model agents of environmental change are divided into two main sources: human activities and natural processes, while environmental responses or conditions are divided into quality and quantity. Although human activities and natural processes shape and determine the state of the environment, the resulting environmental conditions can in turn influence human activities and natural processes. For

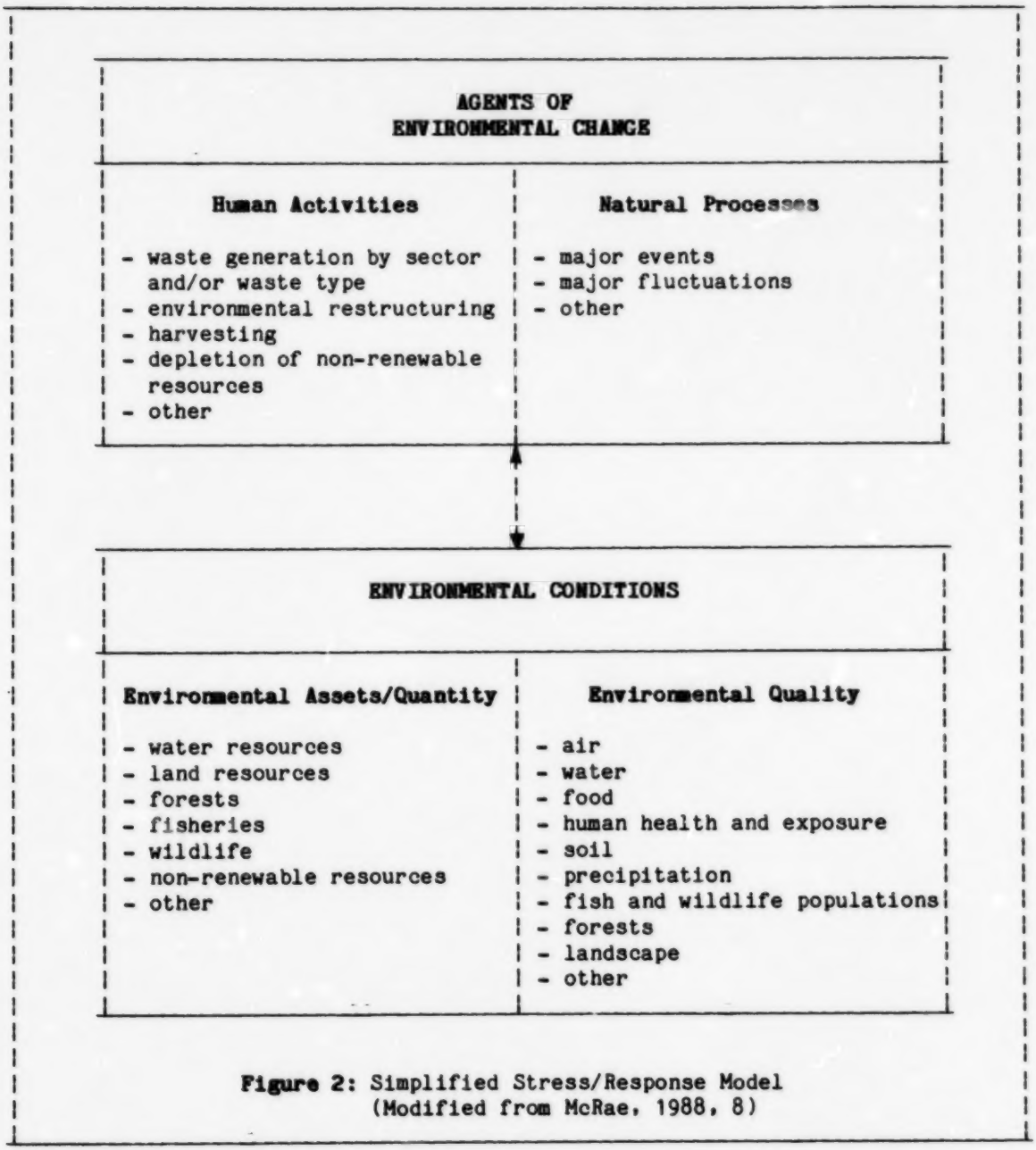


Figure 2: Simplified Stress/Response Model
(Modified from McRae, 1988, 8)

example, carbon dioxide emissions resulting from human activities have modified the atmosphere (environmental conditions) to the point where the natural atmospheric process which determines climatic regimes is changing (global warming due to greenhouse effect). Therefore, a truly comprehensive set of SOE indicators would not only describe environmental conditions - which include environmental assets and quality, but also agents of environmental change - which include human activities and natural processes (see Appendix A for complete list). A comprehensive profile of both stress and response indicators are necessary to understand trends in environmental conditions. Such an understanding is necessary to anticipate change rather than simply respond to observed change.

2.0 DESIRABLE CHARACTERISTICS OF SOE INDICATORS

The following section provides a set of guidelines designed to assist data holders and the SOE reporting community in selecting appropriate SOE reporting indicators. Data holders are obviously most qualified to identify which measures are most representative of the state of the phenomena under study. Statistics Canada (1986, 4) explain that in the course of compiling the statistical compendium which accompanied the 1986 SOE Report 'Human Activities and the Environment', "... the selection of material to display particular themes was heavily dependent upon the advice of subject matter specialists". The criteria presented below can serve as a systematic check list to help experts choose indicators which are compatible with SOE objectives. Appendix B provides a summary of these criteria in a quick-reference format. No single indicator will likely meet all of the following criteria. However this list should provide a framework which will facilitate or guide the selection, evaluation, and/or development of suitable SOE indicators.

While initial SOE reporting efforts are focussing on the use of existing data, an important longer term objective of the SOE reporting program is the identification of data gaps. As our knowledge and understanding of the environment increases and as the SOE program evolves, the need to improve existing indicators and to develop new indicators will become increasingly important. In fact, Liverman et al. (1988, 134) warn that in many cases existing indicators are not the most sensitive or useful measures. The list presented below is equally applicable to the development of new indicators as well as the selection of existing indicators from an SOE perspective.

2.1 Feasible to Obtain

The feasibility of obtaining SOE indicators relates to the cost, time, and difficulties associated with their acquisition.

Availability

SOE indicators should be available and accessible. A common approach to identifying the optimum set of indicators is to match the ideal indicators (demand) with available supply (reality). In many cases, the demand may not match reality (see Sheehy, 1989, 55). This is not surprising given that in many cases environmental data are "... collected for purposes other than environmental analysis and tend to be oriented towards the needs of particular programs and policy objectives" (Statistics Canada, 1986, 4).

While in some cases it may be desirable to initiate new environmental data baseline surveys, initial efforts should make use of existing data as much as possible. Data should be available for more than one time period to enable the identification of trends (see section 2.5) and the security of data monitoring programs should be reasonably stable to ensure future comparable data.

Complexity

SOE indicators should not be so complicated to obtain that it discourages regular monitoring or measurement. The identification of groundwater contamination sources is an example of environmental stressors which are difficult to inventory and monitor given that the number and location of these sources can fluctuate significantly. In this case, it is probably more appropriate to focus on environmental condition indicators, such as groundwater quality, rather than on potential causes of contamination.

Time

The amount of time required to obtain an indicator may affect the relevance (timeliness) of the indicator. For instance, post-processing of the acquired data may significantly delay its availability. In some cases, quinquennial census data are not available until one or two years after the census. Also, the length of time and/or frequency of sampling required could also influence costs.

Cost

The cost associated with obtaining the SOE indicator should not be prohibitive. Similarly, the cost of obtaining or using the indicator should correspond to the importance of the results (Wessels Boer, 1983, 402). Availability, complexity, and time can all influence cost.

2.2 Scientifically Credible

To assess the overall scientific credibility of an indicator the following criteria should be evaluated: the assumptions or knowledge used to determine if the measure is representative of the phenomena under study; the methods used to measure or present the indicator; and

finally the accuracy and reliability of the technology used to measure the indicator.

Assumptions

Indicators are based on an understanding of the relationship (correlation) between the indicator and the phenomenon under study. Such understanding must be accurate and scientifically defensible. For example, human morbidity or mortality may in reality be excellent indicators of specific environmental problems, however there is little scientific evidence linking human health affects to environmental conditions with any degree of statistical validity (Statistics Canada, 1986, 4). The assumptions inherent in models, theories, hypotheses, etc. which describe relationships should be well tested and the results should fall within acceptable confidence limits. Such limits will vary according to statistical technique or scientific evaluation procedure.

Methodology

The methods used to measure indicators can influence the accuracy and credibility of an indicator. For example, "if the indicator is amount of dissolved oxygen (DO) in the water aimed at the protection of benthic organisms, and the target species cannot survive below a particular level of DO, then the monitoring should be done at the time of day when DO is at its lowest level, and the measurement should be taken from the bottom of the water column where the organisms are located" (Council on Environmental Quality, 1984, 438).

Similarly, the methods used to classify and present indicators can also affect their accuracy. The use of averages, aggregates, indices can camouflage real variability, anomalies, or trends. Great care must be taken in choosing the measurement scales to ensure that the indicator is truely representative of the phenomenon under study.

Technical

The most appropriate technology (e.g. measuring instruments) should be used to ensure accuracy. The potential and limitations of this technology should be clearly understood. For example, satellite imagery will vary in accuracy according to the pixel resolution obtained.

2.3 Understandable

SOE indicators should be easily understood and interpreted by Canadians. While it is important for those completing indicator research to understand the technical aspects of indicators, such information may not be relevant to Canadians. It is important that Canadians understand what the indicator represents and be able to assess the significance of the values.

Reference Thresholds

Determining how to interpret an indicator is one of the most important challenges of SOE indicator research. Environmental quality is a concept based on human values. Indicator research involves quantifying those human values to determine acceptable and non-acceptable conditions. Threshold levels identifying normal, problem, critical, and irreversible ranges of values should be identified for appropriate SOE indicators and the relative importance and implications of these thresholds should be clearly explained and communicated. As described in "Environmental Peacekeepers" (Science Council of Canada, 1988, 17) an indicator must relate to some understanding of what constitutes a 'healthy' or 'degraded' state. Information on the level of air or water pollution, or the level of toxic contamination in food, or on the extent of the depletion of a particular resource does not by itself provide an understanding of the state of the environment. Such indicators must be referenced to known threshold values (e.g. acceptable and non-acceptable levels) so that Canadians may understand the environmental and human health implications. Thus, an indicator should be "...linked through scientific documentation to human or environmental health consequences and should have a means to display those consequences in such a way that personal behavior and public decisions can respond to it" (Council on Environmental Quality, 1984, 438).

Data Transformation and Presentation

The techniques used to transform and present indicators can have an important impact on understanding. Absolute data values such as the amount of prime agricultural lands lost to urbanization within a province may not be as meaningful as knowing what percentage of the total prime agricultural lands in the province or country that this loss represents. A ratio measurement scale which presents data with reference to a common denominator enables comparisons and helps identify the significance of values.

2.4 Provide Early Warning Detection

The effects of environmental stressors may be detected at different levels of ecological organization such as cells, tissues, species, populations, or complete ecosystems. Environmental effects will commonly work their way through the food chain. For example, the presence of toxic contamination can move from cells to species to communities. Richardson (in Stokes and Piekarz, 1987, 17) explains that indicators at higher levels of organization reflect stresses and effects which occurred at lower levels in the past. Therefore, indicators at lower levels of organization can be used to predict and/or anticipate what might happen at higher levels of organization in the future (De Wolf, 1983, 357).

A good SOE indicator is one which detects an environmental problem at low levels of ecological organization so that proactive measures can be taken to avoid impacts at higher levels. For example, while population counts of threatened or endangered species might be a great

indicator of a specific environmental problem such as habitat loss, most would agree that at this point the problem has advanced well beyond an acceptable level. Also, if a particular species is chosen as an indicator, it is preferable to monitor those species which have a narrow range of adaptability to changes in environmental conditions, rather than species tolerant of wide variations in conditions. Therefore a good indicator species functions in a narrow ecological amplitude (Odum, 1971, 139 and De Wolf, 1983, 355).

2.5 Enable the Detection of Temporal and Spatial Trends

The availability of SOE indicators over time and space is necessary to identify environmental trends and provide comprehensive national assessments. Temporal trends are required to gauge whether or not environmental conditions are stable (unchanged), improving, or deteriorating, and spatial distribution patterns are useful to identify concentrations or "hot spots" where environmental conditions are degrading or improving.

Applicable for Different Regions and Scales

When possible, indicators should be geographically referenced to allow the identification of spatial patterns and trends. It is important that they be applicable for different parts of the country and that they allow aggregation to provide national overviews and assessments. However, in some cases, environmental problems which are nationally significant remain local in geographic extent (e.g. loss of prime fruitlands) and it is not appropriate or possible to obtain data for the whole country.

Consistency of Methods

Consistent methods to acquire, classify, and interpret SOE indicators must be used from region to region. If not, it becomes difficult to aggregate these indicators to provide a national overview. Statistics Canada (1986, 4) explains that "... even where provincial or municipal statistics exist as in the areas of wildlife populations or land use, lack of classification systems and concepts and differences in survey techniques make it difficult to put together a national presentation". As much as possible, SOE indicators should be acquired, classified, and interpreted using consistent and accepted methods. Otherwise, the implications of the varying methodologies should be explored to assess the feasibility of rendering them compatible. For example, if indicator values were classified using different techniques and the raw data are still available, it is still possible to reclassify them using a consistent technique.

Predictive Models

The sampling interval of SOE indicators, although varying according to the phenomena under study, must be frequent enough to detect trends and ideally should be part of a historic time series that can illustrate long-term trends. Indicators which are monitored over time may be used to build or develop predictive models. In its simplest

form this consists of using time series data to establish a trend and in turn extrapolating that trend into the future. Such models, depending on their scientific credibility and predictive power, may be important for predicting or anticipating future environmental chang scenarios and may assist in the development of proactive environmental management plans and in making informed decisions.

2.6 SOE Indicator Documentation

Relevance of SOE Indicators

An SOE indicator "... must be relevant to some understanding of how the environment works" (Science Council of Canada, 1988, 17). It is possible to have a good environmental effects indicator without understanding what influenced or caused the effect. For example, Sindermann (1988, 937) explains that "at present, the effects of pollution cannot be separated clearly from the effects of the many other stressors to which fish populations are subject". In such cases, even if indicators are detecting an environmental problem (e.g. decrease in fish populations), it may be difficult to respond with appropriate measures if the cause of the problem is not clearly understood. As such, all environmental effects indicators should be accompanied by documentation identifying the possible source of the effect in question just as stressor indicators should identify the potential effects of the stress.

Rules for Indicator Application

Each indicator should be accompanied by appropriate text describing the background assumptions used to choose the indicator and guidelines or rules for the use and interpretation of the indicator. The potential uses as well as the limitations of the indicator should be included.

3.0 CURRENT AND PROPOSED INDICATOR RESEARCH INITIATIVES

3.1 Purpose of SOE Indicator Research

The overall objective of SOE indicator research is to develop a series of "stressor" and "response" indicators that together give a comprehensive picture of how and why environmental conditions are changing in Canada. Such a set of SOE indicators is required for national SOE reporting in the 1990's. Both the development of an SOE Information System and the production of national assessment reports depend on the availability of a comprehensive set of indicators. This set must be flexible in the sense that it could be amended or modified as the SOE reporting process evolves. It can also serve as a source list or guide for more detailed or specific initiatives using indicators.

Obtaining a comprehensive set of national SOE indicators is a major priority of the SOE reporting program. Its importance has been stressed in a number of key documents setting the direction and

mandate of SOE reporting. For example, the importance of identifying environmental trends is emphasized in the results of the SOE Workshop (November, 1987) entitled "A Strategic Direction for State of the Environment Reporting". A meaningful and agreed upon set of indicators was cited as a first requirement necessary to obtain an understanding of environmental trends in Canada (Hickling Management Consultants, 1987, 5). Similarly, the Stakeholder Group on Environmental Reporting explain that Canadian's "... require indicators which show whether human health, natural resources, and ambient quality of the environment is improving or getting worse, what the causes are, and what is being done to maintain environmental quality and stocks of natural resources" (1987, 8). The Federal Environmental Quality Policy Framework identifies the need to establish an SOE reporting system to provide credible information on environmental quality and to identify emerging environmental problems and focus preventive actions. A key element of this system is the development and maintenance of an SOE data base. Both these initiatives clearly require a comprehensive set of national SOE indicators.

3.2 Where Do We Go From Here?

Partnership Approach for Comprehensive SOE Indicator Research

The development of a national set of SOE indicators represents an important, however, ambitious task. The Strategies and Scientific Methods Division of the SOE Branch is already contributing approximately 45% of its operating budget towards this initiative. One way to increase the effectiveness of this commitment is through partnerships with agencies who share an interest in environmental indicator research. As such, it is recommended that an SOE Indicator Network be established in DOE headquarters and regions which could be expanded to include other government departments, provinces and territories, research institutes, academic institutions, non-government organizations, etc. in the future.

The main tasks of this Network will be to:

- lead, initiate, encourage, and coordinate SOE indicator research and prepare a plan detailing desirable SOE indicator initiatives. This plan should be matched with a list of indicator research initiatives which are planned by other agencies to identify indicator research opportunities and gaps. For example, the underlying purpose of an SOE Indicator Network is to take advantage of ongoing activities in various responsibility centres which could complement or contribute to the national indicator initiative.

- evaluate the suitability of planned or proposed indicator research projects in the context of the overall SOE indicator research objectives and plan.

- monitor overall SOE indicator research progress; and

- review and evaluate research results and proposed indicators for national SOE reporting.

The critical role of data holders and the scientific community as members and participants of this Network must be emphasized. While, members of the SOE Branch can coordinate and show leadership to support the activities of the SOE Indicator Network, they are not adequately equipped, both in expertise and resources, to identify the most appropriate SOE indicators for all components of the environment within an acceptable timeframe. Data holders can also provide special insight into the potential applications and limitations of the indicators.

Through a Network approach, a comprehensive set of indicator initiatives which together contribute towards achieving a national set of SOE indicators will be possible.

3.3 Current SOE Branch Indicator Projects

A number of SOE indicator research projects initiated by the SOE Branch are currently underway. These are directed and managed by the Strategies and Scientific Methods Division.

Inventory of Environmental Data Bases

Environment Canada and Statistics Canada are jointly establishing a national SOE Information System as part of the SOE reporting program. An important module of this Information System is a Database Reference Component designed to locate more detailed SOE data/information held in DOE, other Government Departments (OGDs), and eventually provinces, territories and possibly municipalities. The environmental data base inventory necessary to build this Database Reference Component will be invaluable for SOE indicator research. It will show potential SOE indicator data and facilitate their access. The inventory will also be useful to identify key individuals (data holders) who may be able to contribute to the SOE indicator research initiatives.

Literature Review of Indicator Research

This project provides an assessment of environmental indicator research based on a literature review. It includes an assessment of the state-of-the-art with respect to indicator application and research, particularly in North America, Europe, and by the United Nations, and other international organizations. The more useful research documents are annotated. The concept and use of indicators for comprehensive SOE reporting purposes are highlighted.

Sustainable Development Indicators

This project develops a framework, an approach, and criteria for indicators that show progress towards sustainable development. Indicators of sustainable development should detect changes and trends in socio-economic activities that affect Canadian's progress towards a state of environmentally-sustainable development.

Overview of Methods for Interpreting and Presenting Data on Contaminants in the Environment

This project reviews methods for interpreting and reporting data on contaminant levels in the marine environment. The report will also evaluate the results of a pilot study undertaken between the SOE Branch and the Environmental Protection Branch (Pacific and Yukon) in which reporting methods for the marine environment were developed and applied.

St. Lawrence Pilot Project

This pilot project is designed to demonstrate the utility of a cross-sectoral approach for assessing the state of the environment for the St. Lawrence. An important component of the project consists of identifying the main environmental stress and response indicators for the St. Lawrence. Major data gaps will be identified by matching ideal indicators against available data supply.

3.4 Proposed SOE Branch Indicator Projects for 1989-90

The following are proposed SOE indicator research projects for 1989-90 fiscal year. The descriptions of these projects will become more specific as the terms of reference are developed. These initiatives are primarily designed to meet the following objectives:

- Assessing the current state of indicator use and utility in Canada;
- Identifying, applying, and evaluating sample sets of SOE indicators through pilot projects; and
- Through a phased approach, eventually obtaining a comprehensive set of SOE indicators.

Assessment of Use of Environmental Indicators in Canada

Complete a comprehensive assessment of existing use and utility of environmental indicators in Canada. This initiative will be carried out by extending the literature assessment through consultations with indicator research authorities.

SOE Indicator Prototype Project for Marine Environment

Complete an indicator pilot study for the marine environment. Three major phases are envisaged:

Phase 1: Identify an ideal set of indicators required to provide a comprehensive assessment of the state of the marine environment in Canada and compare this set to existing data supply to determine data gaps. An organizational framework will be developed or adopted to organize these indicators.

Phase 2: Consult with specialists to reach a concensus on which of the available indicators are the most appropriate (possibly through a workshop).

Phase 3: Prepare a prototype report identifying the temporal and spatial trends of key indicators chosen for this sector.

Application of Sustainable Development Indicators

This project will test the viability of the framework and the identified indicators (described in 3.3) using one resource sector. Following an evaluation and possible refinement of this approach, the framework and criteria will be applied to other resource sectors.

APPENDIX A

ORGANIZATIONAL FRAMEWORK FOR SOE INDICATORS

A comprehensive set of SOE indicators would describe agents of environmental change (including human activities and natural processes) as well as environmental conditions (including environmental assets and quality).

AGENTS OF ENVIRONMENTAL CHANGE	
HUMAN ACTIVITIES	**EXAMPLES**
Waste Generation by Sector and/or Waste Type	
. Mining and smelting	. Emissions, tailings production, effluent volumes
. Manufacturing	. Emissions, waste generation, effluent discharges
. Municipal	. Sewage effluent discharge, waste landfilled/incinerated/ recycled
. Energy	. Emissions, waste generation
. Transportation	. Emission, spills
. Other	
Environmental Restructuring	
. Building	. Building starts and completions, land and habitat conversion
. Transportation	. Corridor construction, airports, land and habitat conversion
. Agriculture	. Land conversion, wetland drainage application of pesticides

Harvesting	
. Fisheries	. Catches by fish, fishery, zone; trends
. Agriculture	. Yield by commodity and area; trends
. Forestry	. Tree harvest by area, replanted areas; trends
. Hunting and Trapping	. Wildlife harvest by species, area; trends
Depletion of Non-Renewable Resources	. Mineral/ore/fuel production by region, province
Other	. Non-Agricultural pesticide application
NATURAL PROCESSES	**EXAMPLES**
Major Events	. Floods, droughts, fires, earthquakes, landslides, meteorological events, volcanic eruptions/fallout, tsunamis, avalanches
Major Fluctuations	. Trends in river and lake levels, trends in forest disease, climate change, changes in air, water and soil characteristics, natural landscape change, rates of erosion
Other	. Dust storms

ENVIRONMENTAL CONDITIONS	
ENVIRONMENTAL ASSETS/QUANTITY	**EXAMPLES**
Water Resources	. Supply quantity and area statistics
Land Resources	. Supply quantity and area by classification
Forests	. Supply quantity and age statistics
Fisheries	. Population and stock size statistics
Wildlife	. Population and location statistics
Non-Renewable Resources	. Mineral and location statistics
Other	
ENVIRONMENTAL QUALITY	**EXAMPLES**
Air	. Levels and trends in air pollutants by region/pollutant
Water (freshwater and marine)	. Levels and trends in water polluting substances
Food	. Levels and trends of contaminants in foodstuffs
Human Health and Exposure	. Toxic substance analysis in body fluids, tissues
Soil	. Organic matter content, erosion rates, salinization, acidity, etc.
Precipitation	. Acid deposition rates

Fish and Wildlife Populations	. Toxic substance analysis and trends population dynamics, species diversity, endangered species, occurrence of lesions and/or disease
Forests	. Forest depletion rate, cutting, restocking, species diversity, disease, pest, and fire trends
Landscape	. Critical land conversions such as prime agricultural land, protected areas and reserves
Other	

Source: (Modified from McRae, 1988, 8)

APPENDIX B

The following quick reference table provides a summary of desirable SOE indicator characteristics. It is designed to be used as a check-list to rate or evaluate current and potential SOE indicators. The right side of the table is left blank for this purpose.

SOE INDICATOR SELECTION CRITERIA AND DESCRIPTION	COMMENTS
FEASIBLE TO OBTAIN	
Availability: SOE indicator data should be available and accessible. Initial emphasis is on use of existing data.	
Complexity: SOE indicators should not be so complex as to discourage regular monitoring or measurement.	
Time: The amount of time required to obtain SOE indicators should not diminish the relevance of the indicator. For example, in some cases post-processing of data may delay their release for several years.	
Cost: The cost associated with obtaining the indicator should correspond to the importance the indicator and should not be prohibitive.	

SOE INDICATOR SELECTION CRITERIA AND DESCRIPTION	COMMENTS
SCIENTIFICALLY CREDIBLE	
Assumptions: The relationship between the indicator and the phenomenon under study must be scientifically defensible (e.g. within acceptable confidence limits).	
Methodology: Methods used to acquire, analyse, and present indicators should not distort original data. For example, methods used to classify indicator values should eliminate incidental detail and retain relevant information.	
Technical: The most appropriate technology (measuring instruments) should be used to ensure accuracy.	
UNDERSTANDABLE	
Reference Thresholds: The indicator must relate to some understanding of what constitutes a 'healthy' or 'degraded' state. Indicators must therefore be referenced to known threshold values so that Canadians may understand the environmental and human health implications of results.	

SOE INDICATOR SELECTION CRITERIA AND DESCRIPTION	COMMENTS
UNDERSTANDABLE	
Transformation & Presentation of Data: Techniques to transform and present indicators should strive to maintain meaningfulness and emphasize significance. For example, ratio measurements show relativity while absolute values have limited interpretive value.	
EARLY WARNING DETECTION	
The indicator should measure change at the earliest stage possible, ideally before changes progress to higher levels in the ecosystem. For example, endangered species can be clear indicators of a degraded state, but earlier indications would be more desirable.	
ENABLE DETECTION OF TEMPORAL AND SPATIAL TRENDS	
Applicable for Different Regions and Scales: Indicators should be geographically referenced to allow identification of spatial patterns and trends. Aggregation should allow national overviews for nationally available indicators.	
Consistency of Methods: Consistent methods to acquire, classify and interpret SOE indicators must be used from region to region.	

SOE INDICATOR SELECTION CRITERIA AND DESCRIPTION	COMMENTS
ENABLE DETECTION OF TEMPORAL AND SPATIAL TRENDS	
Predictive Models: Indicators which are monitored over time are required to establish trends and may be useful to develop predictive models necessary for proactive planning and management.	
RELEVANCE OF SOE INDICATORS	
It should provide an integrated and comprehensive assessment of how and why the observed phenomenon is changing, and should communicate what the implications of these changes are for Canadians.	
RULES FOR INDICATOR APPLICATION	
The indicator should be accompanied by a listing of guidelines for its proper interpretation. Included should be assumptions made, potential uses and limitations.	

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